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MANAGING OUR ENVIRONMENT THROUGH AGRICULTURAL RESEARCH

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The present decade will in all likelihood be remembered as the time when people became concerned about the environment. Most of us now realize that nature's treasures must be used more discriminately than they have been in the past if man is to continue to prosper, or indeed survive. The Earth's resources are as finite as the blades of grass in a meadow. There are only so many acres of land, so many gallons of water, so many cubic feet of air. We cannot manufacture these basic requirements of life. Unfortunately, we—including agriculture—are still exploiting them. It behooves us to manage our resources better than we have.

There is bound to be disagreement on how to go about it. After all, a good many of our present environmental difficulties are traceable to man's earlier efforts to change his environment. Caves were uncomfortable, so man built houses. The houses got cold; so he lit fires. Sewage accumulated; so he dumped it into the nearest river. All of these efforts were doubtless hailed as milestones in environmental management, as in the short run they were. Eventually, however, they led to widespread pollution of soil, air, and water.

Now, the flush toilet challenges the automobile as a single invention producing horrendous damage to our environment. Everyone who uses this fixture is reminded daily that water is the place to put filthy refuse. How can we help but learn such a personal lesson repeated so often? How can we regard any pond, lake or stream as anything but a place for refuse after such thorough indoctrination.

No one can predict with certainty that a given technological innovation will be without drawbacks. Persistent pesticides are an example. Nevertheless, it is to technology that man must look for the answers to environmental problems. Society has grown too complex to permit a mass movement back to the simple life.

Histroy offers the environmentalist some guidance in his choice of technologies; some past scientific efforts have contributed to environmental quality, some have not. Overall, the agricultural scientist's record in this respect has been good. And through diligent application of agricultural science, some of our environmental problems—suburban erosion or stream siltation, for example—can be solved.

But new ideas will also be needed, particularly concepts that are broad enough in scope to help solve future as well as current environmental problems. We are reorienting much of our research effort to develop this new knowledge.

Of foremost importance in any scheme to manage the environment is public safety. We must be able to see to it that food, water, and air will be free of harmful contaminants. Agricultural chemicals, for example, have provided man with a shortcut to large-scale production that could eliminate hunger. Some of these chemicals, however, particularly the more persistent pesticides, also contribute unwanted substances to the environment. In those cases where we are unable to find ways to use chemicals safely with respect to all environmental values, we will need to replace chemicals with other production techniques. This is the aim of scientists who are working on biologic control of insects.

A concept that is central to a well-managed environment is recycling. We must learn to reuse things—sewage, tin cans, old car bodies. Here, too, agricultural scientists are making progress. In Phoenix, Ariz., they are putting city sewage effluent through soil filters to purify the water, thus opening up the possibility of a new, practical way to increase municipal water supplies. Another team of scientists at Beltsville, Md., is raising house fly larvae on chicken litter, feeding the larvae to chickens, then using the resulting litter to grow more larvae. In California, tomato processing is being done with mobile units in the fields where the tomatoes are grown, and the residue from the processing spread on the fields to replenish the soil.

Within the last several years, increasing concern over environmental quality has led to new research endeavors to insure prevention of pollution of soil, water, air, and plants in both rural and urban areas.

The Agricultural Research Center at Beltsville, Maryland, lies like a large green island in the sea of shopping centers, housing developments, and superhighways that span the Washington-Baltimore corridor. Bisected by U.S. Route 1 into Agricultural Research Center East (The Farm) and Agricultural Research Center West (Plant Industry Station), the Center collectively is an area landmark.

But its pastoral beauty belies the true nature of the Agricultural Research Center. It is, in fact, a dynamic complex of research activity that has made major contributions to a revolutionizing American Agriculture. Established in 1910, the Center rapidly achieved its position as the leading and most diversified agricultural research complex in the world. Its international repute attracts visiting scientists from many countries.

Organizational structures have changed periodically over the years. In 1972, research at Beltsville was realigned into nine Institutes, comprising 67 Laboratories. Each of these Institutes is concerned with one or more areas of study designed to provide continuing solutions to ever-changing problems and needs.

I am a member of the Agricultural Environmental Quality Institute with its 12 Laboratories.

Since man's environment - air, soil, and water - may be affected favorably or unfavorably by agricultural production, research in our Institute is devoted to developing agricultural practices that minimize or avoid damaging the environment.

Because of the vast and increasing need of the world for food and fiber, the Institute is also searching for ways to reduce the adverse effects of pollution on agricultural production.

Research is underway to develop safer pesticides; devise cultural, mechanical, and biological alternatives to objectionable pesticides; measure the degradation of pesticides and determine effects of heavy metals in air, soil, water, and plants; develop means of using sewage sludge to improve agricultural soils; develop systems for recycling animal wastes; revegetate desolated strip-mine areas; and identify the effects of air pollutants on plants.

1. Agricultural Chemicals Management Laboratory - How pesticides, fertilizers, and pollutant metals such as the heavy metals affect the environment and how these effects can be controlled by improved management practices are studied in this Laboratory. The objective of this research is to improve agricultural management, productivity, and food quality, while minimizing possible hazards to the environment from agricultural chemicals.

Work on pesticides emphasizes nonpersistent carbamate insecticides. Lead, cadmium, and mercury are being scrutinized closely in an attempt to understand their soil chemistry. Present work on fertilizers is directed toward development of improved criteria for soil testing, so that farmers can avoid applications of phosphate fertilizers except when actually needed.

2. Air Pollution Laboratory - The effects of air pollutants on a broad spectrum of plant species are investigated, and technology for minimizing and preventing air-pollution damage to plants is developed. Most of the research involves work with ozone, sulfur dioxide, and ethylene - all major gaseous pollutants in the Northeastern United States.

Plant-damaging concentrations, especially of ozone, exist occasionally in rural areas of this region. Facilities are available to exclude pollutants by filtration, so that yield and quality of plants in clean

air may be compared with those of plants in unfiltered air. In addition, plants are exposed to pollutants in special chambers under controlled environmental conditions to determine the mechanisms of the pollutants' actions. Major emphasis is placed on identifying pollutant-tolerant varieties of agronomic, vegetable, and ornamental plants.

3. Analytical Chemistry Laboratory - The Laboratory seeks new and improved methods for detecting and analyzing pesticide chemicals in soil, air, water, and agricultural products; and data on the distribution, dispersion, rates of disappearance, and breakdown products of pesticide chemicals.

Scientists here have pioneered in the development and use of selective phosphorus and sulfur detectors for gas and liquid chromatography, and the development of new techniques and apparatus for quantitative thin-layer chromatography. They have produced time- and money-saving procedures for residue analysis that are widely used throughout the world.

4. Biologically Active Natural Products Laboratory - Insect attractants repellents, toxicants, anti-metabolites, and antifertility agents - these are some of the compounds that scientists are trying to isolate, identify, and synthesize from plant and animal sources. Various analogs and homologs of such compounds, as well as substances with possible juvenile-hormone effects, are synthesized.

Naturally occurring compounds having tumor-inhibiting properties of possible medical value are isolated, identified, and synthesized in cooperation with the National Cancer Institute. Another aspect of the program involves screening compounds electrophysiologically to determine their ability to attract or repel insects, part of a basic study on insect communication.

5. Biological Waste Management Laboratory - Studies of the beneficial uses of sewage sludge on agricultural land are underway. Various methods of incorporation sludges into the soil to improve it are being investigated, along with resulting effects on soil, plants, and water.

Processing of animal manures for livestock feed is another area of work. Previous research established the nutritive value of poultry and other animal manures as feed supplements, particularly for ruminants. Scientists are now working to develop effective methods for pretreating and processing these wastes, as well as looking into possible hazards. Additional studies are directed at increased efficiency in producing insect larvae from livestock and manure for use as a feed additive.

Emphasis is being placed on developing fertilizer and management practices to help revegetate strip-mined areas with useful forages.

6. Chemical and Biophysical Control Laboratory - New chemical, biochemical, and biophysical methods of controlling insects are investigated. Photoperiodic effects on diapause (hibernation) of some of our most damaging agricultural insects are studied, so that these effects - or the underlying biochemical processes involved - can be used for insect control. Promising field-plot experiments using artificial illumination against insect diapause are being expanded.

New insecticides and new application techniques are being developed, in cooperation with other national and international agencies, to control insects dangerous to agriculture and public health on international aircraft flights and around airports. New physical and chemical methods are being investigated for control of flies affecting man and animals. Research is being conducted on feed-additive larvicides for fly control on livestock.

7. Chemicals Coordination Laboratory - A collection of over 30,000 organic compounds, which serves as a source for new insect-control chemicals, is maintained here. In cooperation with industrial laboratories and other ARS field laboratories throughout the United States, the search continues for effective insecticides with limited persistence that produce minimum adverse environmental effects to replace DDT and other undesirable chlorinated-hydrocarbon insecticides.

8. Insect Chemosterilants Laboratory - Scientists seek to find, and make available for use, chemical compounds that interfere with the fertility and reproductive capacity of insects and related organisms. They approach this objective by synthesizing or procuring model compounds, collecting data on their biological activity, and developing structure-activity relationships that serve as guides for further synthesis and selection of active chemosterilants. The chemistry and properties of the most effective compounds are investigated and made available for field tests.

9. Organic Chemical Synthesis Laboratory - Scientists here seek means of controlling injurious insects with chemicals other than conventional insecticides. A broad program is underway to synthesize and develop organic compounds useful as insect-control agents such as attractants, repellants, oviposition stimulants, and juvenile-hormone mimics. Relationships between molecular structure and biological activity are explored to guide the efforts at synthesis. Pheromones (attractants) and other chemicals controlling insect

behavior are isolated, identified, and synthesized. For this purpose, new microanalytical methodology is developed. Formulations and technology needed to use sex pheromones in the direct control of insect pests such as the gypsy moth are being investigated intensively.

10. Pesticide Action Laboratory - New scientific principles are being sought that may insure safe and effective use of chemicals used in the cultivation or control of plants important to society. Ultimate objectives are to improve crop production, insure a high-quality food supply, and safeguard the environment.

Areas of study include: controlling narcotic plants; evaluating new herbicides; new uses for available chemicals in solving specific plant-pest problems; developing new methods of improving absorption, penetration, and movement of pesticides on or in plants; controlling the release of pesticides into the environment; elucidating biochemical and physiological responses of plants to pesticides and the fate of pesticides in plants; discovering the scientific principles underlying effective regulation of weed-seed germination and dormancy; and exploiting the principles of weed biology so as to obtain effective use of herbicides while reducing residues or other hazards.

11. Pesticide Degradation Laboratory - Research is conducted here on the detection, movement, metabolism, photodecomposition, microbial metabolism, uptake, volatility and biomagnification of pesticides in soils and plants and in aquatic and animal systems. Work is done in cooperation with the Environmental Protection Agency and the Food and Drug Administration. Industry and foreign governments are consulted in establishing guidelines, new methods, and criteria for assessing pesticides in the environment. The staff includes biologists and chemists specializing in organic, biological, analytical, and soil chemistry and agronomists, plant physiologists, microbiologists, and animal scientists.

12. Physical Control Laboratory - Better seedbed conditions and more effective fertilizer distribution are studied to reduce farm production costs and improve crop performance. New methods are developed for pesticide application to reduce the amounts of pesticide needed on crops and to limit drift. Instruments are developed to measure and control physical environmental factors. The spectral qualities of the light that triggers changes in plant and insect growth are investigated in laboratory and field studies. Nonchemical methods of controlling insects on livestock are devised and tested. New engineering processes are sought to permit cheap and efficient mass production of insects used in biological control programs.

The processes by which farmstead water supplies become contaminated are investigated. Better designs for new wells and methods of improving old wells are being developed.

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So far this has been a very general description of our Institute. Now, for some specific research projects that are more descriptive of my line of work . . .

The U.S. Department of Agriculture and cooperating agencies have been conducting research along several lines to help cities deal with sewage sludge, the precipitated solid matter that is removed at sewage plants during processing of waste water.

The newest cooperative project with the Maryland Environmental Service (MES) is on composting. This experimental procedure involves aeration of the sludge on a stabilized pad to promote rapid microbiological decay and release of pasteurizing heat. The work is being carried out in an isolated area on the grounds of the Agricultural Research Center at Beltsville, Md. Although 90 acres have been set aside for the experiments, the actual composting will occupy only about 10 acres. The remainder of the site is heavily wooded and will serve as a screening area.

Under terms of a cooperative agreement, MES and the Agricultural Research Service (ARS) are taking sludge generated by the Blue Plains sewage treatment facility, which serves much of the Washington Metropolitan Area. Increasing amounts will be removed from the plant until eventually at least 60 dry tons (300 tons of filter cake) per day will be taken for composting.

Sewage sludge has been used as an additive to municipal refuse to enhance composting, but very little effort has been made to compost sludge itself. The objective was to adapt currently available technology and equipment to the composting of sewage sludge. There was an urgent need to develop within a few months the capacity for processing the 600 tons of sludge per day produced by the Blue Plains Sewage Treatment Plant in the Washington, D.C. area. Considering the composting equipment available, the only feasible choice was a windrow operation.

In December 1972, we obtained several dump truck loads of sludge for experimentation to determine the need for conditioning the sludge to facilitate the composting process. This sludge has a solids content of 20 to 25%.

The aerobic thermophilic compost process is preferred because it is relatively quick. In this process, biological oxidation of the wastes generates heat which may raise the temperature as high as 160°F. The high temperatures should provide some pathogen control.

In dense windrows with little air movement, oxygen levels drop to zero in less than one hour after turning. The aerobic organisms, which need oxygen, provide the heat for warming the windrow. Convective forces cause the air to rise as it is heated, therefore producing a natural chimney effect. The rate of air exchange can be regulated by controlling the porosity and size of the windrow. If the windrow is too dense or too large, it will be mainly anaerobic and will emit offensive odors. Conversely, if the air moves too rpaidly, the temperature cannot rise and the process will be slowed.

A layer of wood chips 15 inches deep and 15 feet wide was placed on the paved area. The sludge was distributed on the chips, at a ratio of one part sludge to three parts chips by volume. The compost machine then formed the sludge and chips into a windrow. Several more turnings were necessary to thoroughly blend the two materials.

The windrow was turned daily. Interior temperatures in the windrows have reached 140°F. Turning mixed the surface material to the center of windrow for exposure to the high temperatures and increased the porosity of the windrow for better air distribution.

After two weeks, the windrow was flattened out in place to a 12-inch layer, and harrowed for further drying. When the material was dried to less than 35% moisture content, a second loading of sludge was applied. Rain or high relative humidity can delay reaching this moisture content. The windrow was then subjected to another two week heating cycle. Additional sludge loadings will be made as long as satisfactory composting conditions can be maintained.

When material is removed from the windrow operation, it is stockpiled for an additional 30 days' curing and storage. The curing phase is expected to improve the quality of the compost for use as a soil conditioner. I also expect that the curing may be important in controlling pathogens.

After curing or windrowing, the chips may be screened out of the compost for reuse as a bulking agent. Further experimentation will determine whether they should be screened out before or after the stockpiling. For some uses, the chips may be left in the compost. When construction at the site is completed, the area will have the capability for composting most of the sludge produced by the Blue Plains Sewage Treatment Plant.

We have been able to receive sludge continuously and start it composting during some relatively unfavorable weather. There has been some odor from the fresh sludge, but better process control at the sewage treatment plant may reduce that. The final product has the same faintly earthy odor as other composts.

NEW WAYS TO FIGHT PESTS: ALTERNATIVES TO PESTICIDES

Good insects that eat bad insects and weeds . . . Plants that protect themselves from pests . . . Chemicals that lure insects to their death . . .

Predators and parasites, resistant plants, and insect attractants can do these things. No panacea, but they are proving effective as biological methods of pest control—alternatives to pesticides that can be safer, cheaper, and more efficient than pesticides now being used.

Some of the general classes of alternative methods, how they work, and the pests they protect against, are as follows:

Predators, parasites, and pathogens (disease-causing organisms) destroy insects and weeds by feeding on or infecting them.

Resistant varieties of plants inhibit attack by insects, diseases, and nematodes (tiny worms).

Attractants lure insects to traps or other devices where they can be killed or sterilized.

Genetic control consists of releases of sexually sterile insects that mate with normal insects.

Bioenvironmental controls are cultural and mechanical practices against insects, nematodes, weeds, and diseases.

Hormone and daylength manipulation disrupt an insect's life cycle and limit the number of insects that survive.

Not all insects are considered pests of man. In fact, we have found ways to make insects work for man. This is often one of time—and patience—in getting these "friendly" predators, parasites, and pathogens established and working for man. It may take 10 or more years.

A tiny flea beetle with fastidious taste is helping to rid the Southeast of alligatorweed, an aquatic weed that clogs waterways. Aquatic weeds are not only a nuisance; they are dangerous as well. They foul propellers on boats, they can harbor diseases, and swimmers drown if they become entangled in them. Alligatorweed can be controlled with herbicides, but heavy, frequent applications are necessary.

"Insect explorers" went to South America where they found tiny beetles that feed only on alligatorweed. After extensive tests to make sure the beetles would not harm man, animals, or desirable plants, scientists released them into clogged waterways in Georgia, Florida, and Mississippi. The beetles have multiplied and now help control alligatorweed in some areas from North Carolina to Texas.

In addition to the use of insects to control aquatic weeds, plant-eating fish, such as the White Amur, and snails, such as the Marisa, show good potential for bio-control of water weeds. This possibility is being studied intensively by ARS scientists.

Insect predators and parasites work for man by feeding on harmful insects and weeds; pathogens are micro-organisms that cause diseases. Nearly every pest is attacked by predators, parasites, or pathogens in nature. Very often, however, enough of the pests survive to damage crops. Furthermore, when pests are accidentally brought to the United States from other countries they almost always leave their natural enemies behind.

For example, the alfalfa weevil, an introduced pest, requires the application of insecticides for its control in the United States. In its native Europe, however, it is controlled primarily by tiny parasitic wasps. In 1957, scientists in the Department began importing these parasites and releasing them in weevil-infested alfalfa fields in Eastern United States.

By 1969—12 years later—the parasites had spread and controlled the weevils to the extent that farmers in New Jersey that year did not need to apply pesticides to protect their alfalfa. The parasites are spreading rapidly and by 1980 could control the weevil in many other areas of the nation.

In the Northeast, the pathogen that causes milky spore disease has long been used to fight the Japanese beetle. Community-wide applications of dust that contains the milky spore bacterium have greatly reduced the damage caused by the beetle. And once established, the disease reduces the need for pesticides.

Another bacterium, Bacillus thuringiensis, attacks many kinds of moth larvae. Moth larvae, or caterpillars, feed on many kinds of plants, and can be very destructive. For example, the cabbage looper feeds on cabbage, lettuce, and many other crops. But, when infested plants are sprayed with the pathogen, cabbage looper caterpillars stop their feeding in a matter of minutes. Soon after, they die.

Many insects are susceptible to virus diseases. The bollworm and the tobacco budworm, destroyers of cotton, corn, tomatoes, and other crops, are attacked by a virus being studied by scientists at the Pink Bollworm Laboratory, Brownsville, Texas. Commercial companies are now developing ways to produce the virus in quantity.

Scientists have also discovered a virus that attacks larvae of the codling moth, the cause of "wormy" apples. We are also studying diseases of house flies and mosquitoes.

Insects respond to various chemical substances in plants in their search for food and to chemical sex attractants produced by the insect for mating. They also respond to light and sound. Attractants are used by scientists to lure insects in traps or other places where they can be killed.

Live, unmated female insects can be put inside traps to attract the males, or, in some species, male insects are put in to attract the females. Once inside a trap, the insects are killed with an insecticide, or, in other traps, they become caught in a sticky substance and cannot escape.

Scientists are devoting considerable research effort toward isolating, determining the chemical structure, and synthesizing sex attractants in order to obtain large enough quantities for use in practical tests for control of several major insect pests.

One of the most powerful attractants is methyl eugenol, a commercially available chemical, which attracts male oriental fruit flies. It is not a sex attractant; it attracts the males for feeding rather than for mating.

Methyl uegenol was used to eradicate the oriental fruit fly from the islands of Rota, Tinian, and Saipan in the South Pacific. First, scientists fortified the methyl eugenol with a small amount of insecticide and put the mixture into small squares of fiberboard. Then, they dropped the squares from an airplane at a rate of 125 per square mile. About a dozen drops were made over a period of several months.

The male flies were highly attracted to the methyl eugenol, and when they landed on the fiberboard, they were killed by the insecticide. As a result, in a few months, only female flies were left on the islands. Their eggs, which had not been fertilized, did not hatch. And when the females died, the islands were free of the pest.

Materials for the project cost about 50 cents an acre. Only about one-tenth of an ounce of insecticide per acre was applied. Formerly, growers applied 3 pounds of insecticide to each acre every year for seasonal control of this pest.

Workers also use methyl eugenol as a quarantine measure to help detect and get rid of oriental fruit flies that may enter the United States in infested fruits and vegetables carried by incoming travelers or by hitchhiking on commercial and military aircraft and ships. Traps that contain methyl eugenol are placed near ports of entry to intercept new infestations.

Scientists have also developed an attractant for yellow jackets. If it proves successful, it could be a boon to campers and picnickers because it can lure the yellow jackets into a trap and away from recreational areas.

Many insects are attracted to specific kinds of light. Blacklight—another name for ultraviolet light—attracts many kinds of insects, such as the pink bollworm, cabbage looper, tobacco budworm, and tobacco hornworm moths. Agricultural scientists in North Carolina found that three blacklight traps per square mile, combined with cultural control, greatly reduced the need for insecticides for control of the tobacco hornworm.

Genetic Control

Scientists are taking advantage of mating habits to get rid of harmful insects. Genetic control was used to eradicate the screwworm fly, a killer of livestock, from the Southeast and to control it in the Southwest and Northern Mexico. Genetic control is also helping to keep the pink bollworm, a pest of cotton, from spreading in California.

The best known example of genetic control is the sterile male technique. In applying this method, scientists first reduce the native population of insects with cultural control, pesticides, or other methods.

Meanwhile, insects are reared in the laboratory and the males are sterilized with radiation from radioactive cobalt or cesium or with sterilizing chemicals called chemosterilants.

The sterilized insects are then released in an infested area— many sterile insects to each male insect in the natural population. When the normal female insects mate with sterilized males, they do not produce young. Sterile male releases are continued and with each succeeding generation, fewer and fewer fertile matings take place. Eventually, the insect is eliminated as the older individuals die off and are not replaced by a younger generation.

In Washington State, scientists are using genetic control in an attempt to control the codling moth in part of the Columbia River Basin. The codling moth is the most destructive pest of apples in the United States.

The release of sterile Mexican fruit flies instead of a spray program is being used in Northern Mexico to prevent establishment of this pest in southern California. Genetic control is also being studied as a possible measure for suppressing certain species of mosquitoes in parts of Florida.

Scientists are also using genetics to breed insects that can pass on inferior traits to their offspring. Such strains of insects might produce fewer offspring, for example. House flies, boll weevils, and some kinds of mosquitoes are candidates for this method.

Hormone and Daylength Manipulation

Turning insects into "freaks" is a new challenge for agricultural scientists. Scientists now know how—at least on a laboratory scale— to reorder an insect's life cycle so it becomes a "freak" that cannot survive or reproduce.

Insects, like plants and other animals, have hormones that help to regulate their body functions. Presence of juvenile hormones in an insect's body makes it grow but not mature. Absence of juvenile hormones allows a young insect to become an adult. If insects get doses of juvenile hormones when they would normally mature, they do not complete their development to the adult stage. These insects are "freaks"—half larva, half adult, that cannot function normally.

Scientists have found substances similar to the juvenile hormone and other hormones in some plants on which the insects feed. The presence of these substances in certain plants might explain why some varieties are resistant to insect attack.

Manipulation of daylength is another way to interfere with an insect's life cycle. Scientists have shown that exposing young corn earworms to a longer period of light than normal in the fall can prevent them from entering diapause, their winter resting condition.

During diapause, an insect's life processes slow down and require little nourishment. In most parts of the United States, if insects did not enter diapause in the fall, they would freeze or starve for lack of food in cold weather.

Integrated Control

Foreign parasites and predators that will not survive here . . . Insects and diseases that adapt to resistant plants . . . Insect attractants that have complex chemical structures that are difficult to duplicate in a test tube . . . These are a few of the challenges facing pest-control scientists. No one method can control every insect, weed nematode, and plant disease. And frequently, it takes a combination of methods to control a single pest. So scientists are working on combinations of new and older methods, combinations known as integrated control.

Expensive? Yes. But compared to the cost of pesticides, applied every year, integrated control is a bargain, indeed. And in reducing pollution and safeguarding the health of man and animals, the alternative methods will continue to pay dividends to future generations.